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BIOLOGICAL EVALUATION OF PINYON PINE MORTALITY, CHIMNEY PEAK AREA, BUREAU OF LAND MANAGEMENT

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ABSTRACT

Black stain root disease, caused by Leptographium wagneri, is causing obvious mortality in single-leaf pinyon, Pinus monophylla, on Bureau of Land Management land in the Chimney Peak area in southeast Tulare County, CA. Bark beetles (primarily Ips confusus) have killed some diseased trees and some pockets of uninfected trees. Pinyon pine blister rust (Cronartium occidentale) has girdled some branches and stems, causing dieback. On an old burn site, young trees have been severely defoliated by the pinyon needle scale, Matsucoccus acalyptus. Black stain is by far the most threatening of these pests. Management alternatives for this disease include (1) no action (combined with monitoring, if desired), (2) fell dead and infected trees plus a 75 foot buffer around each disease center, (3) remove trees in a buffer around infection centers, or between healthy and infested stands, (4) salvage dead and diseased trees, and (5) thin stands to reduce root contact between trees and increase the vigor of the leave trees. The controversy over thinning in black stain areas is discussed.

INTRODUCTION

In 1983 it was determined that pinyon pine blister rust, caused by the fungus Cronartium occidentale Hedgc., Bethel & Hunt, and black stain root disease, caused by the fungus Leptographium wagneri (Kendrick) Wingfield, were

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causing branch dieback and tree mortality, respectively, in single-leaf pinyon (Pinus monophylla Torr. & Frem.) in the Chimney Peak area in southeast Tulare County, CA (Smith 1983). At that time management alternatives presented to the Bureau of Land Management (BLM) were to do nothing, remove dead and dying pinyon, and remove dead and dying pinyon plus a 75 foot buffer around each infection center. Only the latter of these three alternatives has potential for preventing the growth of infection centers.

Because of the size and concentration of root disease centers in the Chimney Peak area, BLM managers decided that Smith's (1983) third alternative, i.e., removal of infected trees plus a 75 foot buffer, would result in an unacceptably large clearcut covering hundreds of acres. Further, regeneration of pinyon on such a clearcut would be difficult or impossible (see Clifford 1987 for problems in regenerating pinyon). Since 1983, mortality has continued, resulting in increasing numbers of dead trees in the area. The resulting fuel load is a fire hazard and there is pressure from members of the public who wish to utilize the trees for firewood. The BLM would like to institute a control program in the area and requested a biological evaluation from Forest Pest Management to describe feasible management alternatives.

OBSERVATIONS

On June 25-26, 1991, USDA-Forest Service, Forest Pest Management and Bureau of Land Management personnel (see Appendix A) visited the Chimney Peak area to observe the present root disease situation and discuss management alternatives. The black stain-infested stand visited (T.23 S., R.36 E., Sec. 28, 34, and 35) was almost pure, mature pinyon pine estimated by BLM personnel to be 80 to 100 years old. A few junipers and Jeffrey pine were present in some areas. In addition, we visited a large old burn (T.23 S., R.37 E., Sec. 31, SW quarter) which was primarily brush with a few large old pinyons and scattered regeneration. The Chimney Peak area is being managed for wildlife, recreation, and visual qualities.

Black stain root disease pockets in the unburned stand were large and recently killed trees were seen. Characteristic stain was found in the bases of trees at three distinct sites. The disease was identified by the characteristic dark brown stain which follows the annual rings.

Bark beetle galleries (probably Ips confusus LeConte) were seen in trunks and large limbs of trees in black stain pockets. There was a small group of trees in T.24 S., R.37 E., Sec.8, NW quarter, that was apparently killed by bark beetles (again, probably I. confusus but possibly Dendroctonus ponderosae Hopkins) in the absence of root disease.

As observed by Smith (1983), pinyon pine blister rust was causing limb dieback in the drainage along the road in sec. 34 and 35.

In the large old burn, heavily defoliated young pinyons were observed. These trees were infested with the pinyon needle scale, Matsucoccus acalyptus Herbert (Hemiptera [Homoptera]: Margarodidae). Approximately 25 - 50% of the young trees, which were generally less than 8 feet tall, were heavily

defoliated by this insect. The heavily defoliated trees only retained 1990 and 1991 foliage.

Minor pests: Other insects observed feeding on the pinyons, such as Retinia (Petrova) sp. (a pitch nodule moth), Dioryctria sp. or spp. (pitch mass borers), and unidentified tip moths, rarely have a significant impact on the health of pinyons.

MANAGEMENT ALTERNATIVES -- BLACK STAIN AND BARK BEETLES

1. No action: Most disease centers will continue to expand and kill additional pinyons. Some centers may remain static or disappear. The rate at which a particular disease center grows and regeneration within the center becomes infected could vary from center to center depending on microsite factors (e.g., soil moisture and temperature), and differences among host trees and possibly between particular isolates of the pathogen.

With the no action alternative, losses to bark beetles can be expected to continue, particularly as long as root diseased trees and drought stressed trees are available. Healthy pinyons in non-drought years usually are not killed by bark beetles.

2. Remove trees in infection centers plus a buffer: This alternative may be most suited to sites that have few or small disease centers where this treatment will not create large openings. This is the only method, based on present knowledge, that can possibly limit the growth of infection centers and actually eliminate the disease. Regeneration can be expected to be difficult (see trials by Clifford 1987). Replanting with resistant species (juniper and Jeffrey pine in this area) might be possible to some extent, although the very limited numbers of individuals of these species present suggests that they are not well adapted to the site.

This alternative would not have a significant impact on the numbers of healthy trees that would be lost to bark beetles.

3. Remove trees in a buffer around infection centers: This technique could be used where root disease centers are too large to clearcut and the BLM wishes to protect healthy stands nearby. A buffer strip one to two trees wide could be cut a certain distance beyond the nearest infected tree. Presumably the buffer would have to be cleared of pinyon seedlings every several years. The optimum distance of the buffer from symptomatic trees could be determined for Chimney Peak by excavating roots to determine the limits of infestation, but 50 feet might be reasonable. The disease center would remain active (i.e., the fungus would remain alive) as long as there were living trees present, but this method would prevent disease spread by root contact across the buffer strip. It would not prevent spread by insect vectors. This method is experimental, and the BLM should monitor tree mortality after the treatment is applied.

4. Salvage dead and diseased trees: This will reduce the fuel present in the area and possibly result in positive feedback from the public. However,

removal of dead and symptomatic trees will not affect growth of disease centers or losses to bark beetles. If the public is permitted to cut down dead and diseased trees, careful control must be maintained to prevent cutting of green trees outside of disease centers. Until it is known whether or not cutting live pinyons attracts black stain root disease vectors, the BLM may choose to avoid doing so in black stain areas.

5. **Thin stands:** In general, thinning trees when they are growing well (in non-drought years) increases their growth rate and vigor, making them more resistant to attack by bark beetles and other pests. However, thinning in healthy stands near black stain centers may attract disease vectors and exacerbate the situation (see pest biology section concerning this controversy).

Within black stain centers, thinning trees to a spacing which would minimize root contact between trees might reduce the rate of spread of the disease.

If stands are thinned, it would be advisable to use presence of pinyon pine blister rust as a marking criterion, i.e., remove trees with cankers on or near the main stem.

With any of the above options, artificial regeneration of undesirable openings could speed up the natural regeneration process and allow establishment of species not susceptible to pinyon black stain and pinyon blister rust, e.g., juniper, mountain mahogany, and Jeffrey pine.

MANAGEMENT ALTERNATIVES -- PINYON NEEDLE SCALE

1. **No action:** Natural factors (predatory and parasitic insects, death of the most susceptible trees, etc.) can be expected to eventually limit populations of this insect. Some heavily defoliated trees will die, possibly from bark beetle attack.

2. **Reduce brush competition:** Removal of brush adjacent to the young pinyons would increase their vigor and improve their chances of surviving and outgrowing current defoliation.

3. **Insecticidal sprays:** Use of insecticidal sprays may be warranted to protect the young trees which are currently suffering from severe defoliation. Timing of sprays is critical, since once the scales have settled down on needles they secrete an impervious waxy covering, and can only be killed with systemic insecticides. McCambridge (1974, attached) recommends spraying egg masses when crawlers start to emerge from the eggs.

4. **Manual removal of egg masses:** Eggs of this insect are laid in masses on the lower bole of the tree and in the duff around the tree. These may be removed by hosing the lower bole with water and raking up the debris from the duff (see attached article by Flake and Jennings 1974). Although it is not possible to

remove every egg, the resulting reduction in numbers of insects would greatly benefit individual trees.

CONCLUSIONS

Black stain root disease is the most serious pinyon pest in the Chimney Peak area. Diseased trees are often killed by bark beetles, but these insects are secondary to the root disease problem. Another insect, the pinyon needle scale, is causing severe defoliation of young pinyons on an old burn. Pinyon pine blister rust is common in one drainage.

Few treatments have been attempted for black stain root disease in pinyon. Research is continuing on this disease, but any treatment undertaken by the BLM should be considered experimental. BLM personnel may wish to document changes in mortality levels in treated areas and, if possible, in untreated checks.

The management alternatives presented above are not mutually exclusive. One or a combination of options may be useful in different situations or sites. It is not appropriate to select one option and apply it to the entire Chimney Peak area.

Ips confusus, the pinyon ips, is not aggressive and generally only kills trees weakened by disease, drought, or other insects. Reducing damage of other pests and thinning overstocked stands will reduce losses to these beetles. Thinning healthy stands in areas with black stain may be risky because of the potential for attracting disease vectors.

The heavy infestations of pinyon needle scale may result in mortality of some young pinyons. Clearing away brush around the trees to reduce competition, manually removing the egg masses and/or spraying the scale crawlers with insecticide should reduce or prevent such mortality.

The pinyon pine blister rust is not a severe problem in this area. If stands are thinned for other reasons, the presence of cankers on or near the main stem of a tree could be used as a marking criterion.

BLM personnel listed questions pertaining to black stain root disease. These questions and their answers are in Appendix B along with a list of questions about the disease that the BLM may wish to answer experimentally.

PEST BIOLOGIES

Black Stain Root Disease

Black stain root disease is caused by the fungus Leptographium wagneri (Verticicladiella wagneri, sexual stage Ophiostoma [Ceratocystis] wagneri). In California the fungus has three host-specific strains that infect either

ponderosa and Jeffrey pine, singleleaf pinyon pine, or Douglas-fir. In most situations the fungus does not cross over between species, even in mixed species stands. Resistance to black stain root disease in single-leaf pinyon, Jeffrey and ponderosa pines, and Douglas-fir has not been identified.

Initiation of disease centers probably occurs when spore-carrying, cambium-feeding beetles (probably scolytids and curculionids) invade tree roots and transmit the spores of the fungus to the tree. The fungus then grows in the wood of the root toward the root collar. Insect vectors in Douglas-fir and ponderosa pine roots have been identified (Harrington et al. 1985, Goheen and Cobb 1978). We believe that there are similar vectors in pinyon pine, but these have not been identified. Bark beetles which attack the trunk, e.g., Ips spp. and Dendroctonus spp., are unlikely to vector the fungus. In Douglas-fir, vectors appear to be attracted to resin (Rudinsky and Zethner-Moller 1967), thus wounding trees or thinning stands may put them at risk for infection. There is strong evidence that vectors are attracted to thinned or disturbed stands of Douglas-fir (Hansen 1978, Lownsbury 1988, Harrington et al. 1983, 1985, Witcosky et al. 1986). Similarly, black stain in ponderosa pine in the central Sierra has been observed to be associated with disturbance such as logging (Cobb, pers. comm.). Thinning studies in ponderosa pine have not been done.

Because of the association of increased vector activity in thinned stands of Douglas-fir, some experts consider thinning in any host species in a black stain root disease area to be a risky activity. Other experts feel that the benefits of thinning (increased vigor of the leave trees and possible reduction of root contact) outweigh the risks. There are no data on thinning in pinyon stands infested with black stain root disease. Because of this controversy, land managers may wish to monitor thinned areas for subsequent disease development.

Once the fungus becomes established in a tree, it spreads locally between trees through rootlet contact or hyphal growth through the soil for short distances and direct infection of small feeder roots. The rate of underground spread in a ponderosa pine stand is highly variable and dependent on species composition, stand density, and site; on the Georgetown Divide, El Dorado County, the average annual radial spread was 4 feet (range 0 to 20 feet). The rate appears to be faster in Douglas-fir. In pinyon the disease has been estimated to spread 40 feet in 6 years (Wagner and Mielke 1961). However, there is evidence that in ponderosa pine some centers do not enlarge (Cobb et al. 1982). It is not known if there are biotic (other than death of all available host trees) and/or abiotic factors that eventually limit the growth of disease centers. An individual disease center may grow, remain static, or even die out. One scenario is that so long as host material is present, the disease will persist in an area. Trees regenerating within centers may escape the disease for decades, but eventually the roots may grow in the vicinity of infected roots, become infected, and die. The rate at which a particular disease center grows and regeneration within the center becomes infected could vary from center to center depending on microsite factors (e.g., soil moisture and temperature), and differences among host trees and possibly between

particular isolates of the pathogen. It seems likely that large, hot fires could eliminate infection centers.

The disease is not long-lived in the absence of live hosts and is thought to only survive a few years in stumps and roots, in contrast to annosus root disease and other root decay fungi which can survive for decades as saprophytes. The report of isolation of the pathogen from the root of a pinyon pine (P. edulis) that had been dead for 10 years (Wagener and Mielke 1961) should be considered to be unusual.

The disease can be identified in a tree by the dark brown to black stain of the xylem at the root collar and in roots. This stain occurs as arcs that follow the annual rings. The amount of stain around the bole varies among trees. It may involve only a small part of the tree's circumference or it may encircle the tree. The stain may be one to many annual rings deep. The stained xylem is at the base of the tree and sometimes only in the roots, and in pinyon seldom extends more than 1 or 2 feet above ground level. In P. monophylla the stain is often a chocolate brown. Blue-stain fungi (associated with bark beetle attack and not causing a root disease) cause blue to black staining of the wood, and the stain grows through the xylem rays and is visible in cut stumps as wedge-shaped discoloration rather than as arcs. Furthermore, since bark beetles frequently attack diseased trees, blue stain fungi introduced by the beetles may obscure the signs of black stain, making diagnosis difficult in bark beetle killed trees.

Infected trees undergo gradual to rapid crown decline prior to mortality. Symptoms of crown decline include reduced terminal growth, needle yellowing and shortening, and premature loss of foliage. Douglas-firs may have grayish-blue resin streaming from the bark at the base of the tree above the stained area.

In ponderosa pine in the Sierra, the disease appears to be more aggressive in moist soil, possibly because of increased survival and growth of fungal hyphae between tree roots. The fungus has been reported to grow better at low temperatures (15°C), thus exposure of the soil to solar radiation in an open stand may reduce the rate of spread of the pathogen. Further, in ponderosa pine the disease appears to spread more rapidly in pure, overstocked stands, probably because of the proximity of susceptible roots.

Pinyon Pine Engraver Beetles

The pinyon ips, Ips confusus LeConte, is a five-spined Ips which attacks Pinus monophylla, P. edulis, P. californiarum, and possibly other pinyon species in California, Nevada, Utah, New Mexico, and Arizona. A closely related species, I. hoppingi Lanier, attacks more southern pinyon species (P. cembroides, P. discolor, P. remota, and possibly other species). Details of the biology of I. hoppingi are not known, but are assumed to be similar to the biology of I. confusus. Attacks of both Ips species on live trees are usually limited to trees which are suppressed, or stressed by dwarf mistletoe, root disease, drought, fire or the attack of other insects. If fresh slash is

available in the spring, pine engravers may build up in an area and cause localized mortality.

Attacks are made with the coming of warm weather in the spring. Pioneering males excavate nuptial chambers in the inner bark (phloem) and release a pheromone which attracts conspecifics of both sexes to the tree. If many beetles are attracted, they may attack nearby trees and cause a group kill. Within a few days of gallery initiation by the male, two to five females enter the nuptial chamber and, after mating, each female constructs an individual egg gallery parallel to the grain of the wood. The nuptial chambers and egg galleries may score the sapwood if the phloem is thin. The galleries are kept open by male beetles pushing boring dust out through the entrance hole. (In contrast, adult galleries of the mountain pine beetle and other Dendroctonus species are packed with frass.) Yellow or red boring dust collecting in bark crevices or spider webs is diagnostic of a successful attack. Eggs are laid in niches along the sides of the females' galleries. Larvae hatch from the eggs and feed in the phloem, generally moving perpendicularly away from the egg galleries. The larvae eventually pupate in cells in the phloem at the ends of their larval mines and transform to adults. The adults are dark brown to black beetles, 3.5 to 4.2 mm long, with the end of the abdomen formed into a concave declivity bordered by 5 spines on each side. Bluestain fungi are usually associated with attack by these beetles.

A new generation is produced in as little as 6-8 weeks in the spring to 4-6 weeks in mid-summer (August). Thus, several overlapping generations per year may be produced. The winter is passed in the adult stage, with large numbers of adults hibernating together under the bark of standing trees.

Outbreaks in standing, healthy trees are sporadic and of short duration, and are often associated with some temporary stress or shock afflicting the host species, such as drought or woodcutting disturbance. Tree killing may occur where green pine slash, which serves as breeding habitat, is left untreated during spring and summer. To be suitable as pine engraver breeding habitat, pine slash must have succulent phloem and remain moderately cool during the beetle development period.

Fresh pine slash caused by thinning, dwarf mistletoe control work, construction or winter storm breakage can be modified in a number of ways to make it unsuitable for pine engraver breeding. One approach to minimizing damage is to schedule slash-generating activities mostly between mid-July and late December, when the slash has a high probability of drying out, heating up, or spoiling before the beetles can complete their development. Utilization of the cut material to the smallest possible diameter will minimize the amount of breeding material available to engraver beetles. If green pine slash must be created during the spring and early summer, slash should be treated to prevent the buildup of pine engraver populations. Because pine engravers can complete their development in about a month under ideal conditions, treatment should be carried out soon after cutting to be effective.

Slash treatment methods which generally work well include chipping, lopping and scattering slash in sunny areas to heat it up, crushing or mashing

slash with logging equipment to make it unsuitable for pine engraver breeding, or piling and burning the slash within a month of cutting. Broadcast burning the slash might work if it could be done without damaging the residual stand. A method which has worked during the summer in hot climates is to pile slash in a sunny area and tightly cover the pile with clear plastic. If the temperature under the bark of slash in all parts of the pile reaches 120°F, all brood currently in the pile will be killed. Lower temperatures will not be effective and, where successful, this method will not prevent reinfestation of slash piles. Because most pine engraver attacks occur within a quarter-mile from the location where the beetles emerged, high value pines can be given some protection by removing fresh pine slash to areas which do not have pines.

Two practices which should generally be avoided are piling fresh pine slash without further treatment, and allowing slash to touch or remain near leave trees.

Mountain Pine Beetle

The mountain pine beetle, Dendroctonus ponderosae Hopkins, attacks the boles of ponderosa, lodgepole, sugar and western white pines larger than about 4 inches dbh. Single-leaf pinyon has been recorded as a host but is not usually attacked by this beetle. Extensive infestations have occurred in mature lodgepole pine forests. Group killing often occurs in mature forests and young overstocked stands of ponderosa, sugar and western white pines.

The life cycle of the mountain pine beetle varies considerably over its range. One generation per year is the general rule, with attacks occurring from late June through August. Two generations per year may develop in low elevation sugar pine.

Attacks may extend from the root collar up to near the top of the bole. Pheromones released during a successful attack may attract enough beetles to result in a group kill. Pitch tubes and red boring dust in bark crevices or on the ground indicate successful attacks.

The adults bore long vertical egg galleries and lay eggs in niches along the sides of the gallery. The adult galleries are packed with frass, in contrast to those made by Ips spp. A "J"-hook is common at the lower end of the gallery. The hatching larvae feed in mines perpendicular to the main gallery and construct small pupal cells at the end of these mines where they pupate and transform into adults. The adults are stout, black, cylindrical beetles 4 to 7.5 mm long with convex abdominal declivities.

The sapwood of successfully attacked trees soon becomes heavily bluestained. The bluestain fungi probably aid in overcoming the defenses of the host tree.

Natural factors affecting the abundance of the mountain pine beetle include low winter temperatures, nematodes, woodpeckers and predaceous and parasitic insects. As stand susceptibility to the beetle increases because of

age, overstocking, diseases or drought, the effectiveness of natural control decreases and mortality increases. Relieving stress by thinning dense stands can prevent some group kills. Individual high value trees undergoing temporary reversible stress may be protected from attack by application of insecticide to the bole.

Pinyon Pine Blister Rust

Pinyon pine blister rust is caused by an obligate parasite, Cronartium occidentale Mein., which has a similar life cycle to white pine blister rust, C. ribicola Fisch. This rust attacks pinyon pines and Ribes (currant). The fungus needs the two alternate hosts to survive, spending part of its life on pinyons and the other on Ribes. The disease occurs throughout the western United States. Infection of pines results in cankers on branches and main stems, branch mortality, top kill, and occasional tree mortality.

Spores (aeciospores) produced by the fungus in the spring in inconspicuous cankers and cracks in the pine bark are wind-disseminated to Ribes where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves reinfect other Ribes throughout the summer, resulting in an intensification of the rust. A telial spore stage forms on Ribes leaves in the fall. Teliospores germinate in place to produce spores (sporidia) which are wind-disseminated to pines and infect current year needles. Following infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, spores are produced on the cankers and are spread to Ribes to continue the cycle. Although blister rust may spread hundreds of miles from pines to Ribes, its spread from Ribes back to pines is usually limited to a few hundred feet.

Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers near the bole will eventually form bole cankers. Bole cankers result in girdling and death of the tree above the canker. Cankers further from the main bole are unlikely to reach the bole and only branch flagging will result.

Environmental conditions are critical for successful infection and limit the disease most years. Moisture and low temperatures favor infection of both hosts, and must coincide with spore dispersal for infection to occur. In California, these conditions occur only infrequently, usually in cool moist sites such as stream bottoms or around meadows. In years when favorable conditions occur high levels of infection can result.

Pinyon Needle Scale

See Forest Pest Leaflet No. 148 (McCambridge 1974, attached) for information on the biology of the pinyon needle scale.

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Experts Consulted

Pinyon needle scales were identified by Mr. Raymond Gill, California Department of Food and Agriculture, Sacramento, CA.

In addition, the following experts were consulted in writing this report:

Katie Clifford, San Bernardino National Forest, Cajon Ranger District, Fontana, CA

Professor Fields W. Cobb, Jr., Dept. Plant Pathology, University of California, Berkeley, CA

Dr. John Kleijunas, Forest Pest Management, San Francisco, CA

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Appendix A

Black Stain Root Disease Field Trip Participants:

Bureau of Land Management:

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Appendix B

Questions and Answers about Black Stain Root Disease

1. How is the disease being transmitted in this area? Enlargement of centers is probably occurring through root contacts or growth of fungal hyphae for short distances (up to 15 cm) through the soil. Initiation of new centers (longer distance spread) is hypothesized to occur through activities of as yet unidentified root feeding insects.
2. How does BSRD resemble other ceratocystic fungi such as Dutch elm disease? Like Dutch elm disease (DED), BSRD is a wilt fungus which kills by blocking the vessels (DED) or tracheids (BSRD) which transport water in the tree. Unlike DED, which is an introduced pest, BSRD is native to pinyon stands in the southwestern U.S. Furthermore, BSRD is confined to the roots and base of the bole, unlike DED which also occurs in aerial plant parts. Thus although both diseases can spread through root contacts, DED is vectored by a bark beetle which feeds on twigs and the tree bole, while the only insects that can vector BSRD are those that feed on the roots. In addition, since DED is an introduced pest, its North American hosts have not been exposed to it in the past and have not evolved resistance or tolerance to the pathogen.
3. Exactly what types of bark beetles and other potential insect vectors are present? The bark beetles whose damage we observed, Ips confusus, are almost certainly not BSRD vectors. Black stain vectors in pinyon have not been identified nor have root feeding insects, to our knowledge, been collected. Evidence from Douglas-fir and ponderosa pine suggests that such vectors would be root feeding bark beetles or weevils, e.g., species of Hylastes, Pissodes, and Steremnius.
4. What other pathogens are present and how do they interact with BSRD? As observed by Smith (1983), pinyon pine blister rust is present in the area. This rust and BSRD operate independently and have limited, if any, effect on each other.
5. Is age and size of pinyon a factor in its susceptibility? Older trees appear to take longer to succumb! Smaller trees, e.g., young pinyons in BSRD centers, have more limited root systems and are less likely to encounter roots of diseased trees than large trees with extensive root systems.

To cause death, BSRD must block water transport in a significant portion, radially, of the active xylem. Larger trees have more xylem and thus may take longer to kill than smaller trees.
6. Are there any resistant pinyon? There are no BSRD resistant pinyon known.
7. Has prescribed burning been effective in any other BSRD disease areas? What does the F.S. think of a limited burn here especially for erosion control purposes? Prescribed burning has not been used to control BSRD. To kill the pathogen in an area, the fire would have to be hot enough to kill infected trees plus a buffer -- similar to clearcutting. A light burn is unlikely to affect the disease, which will survive in infected host trees. We do not have the expertise to comment on burning and its effect on erosion.

8. Is there any evidence that BSRD could be spread by chainsaws and other tools or by other aspects of firewood cutting? BSRD is a disease of living tissue, and it is extremely unlikely that it could survive and grow down the stump through the roots to adjacent uninfected trees, even if the chainsaw cut through infected tissue in a diseased tree, then was used to cut down a live healthy tree.

However, the cut stumps may be attractive to insect vectors of the disease, which would fly or walk into areas near the stumps and dig down through the soil to roots of healthy trees, or attack and inoculate the cut stumps which may remain alive long enough for the fungus to grow through them to roots of adjacent trees. There is good evidence that Douglas-fir stumps are attractive to BSRD vectors, but the situation in pinyon is unknown.

9. Is BSRD present throughout pinyon's xylem system or just in roots and lower bole -- and -- is this related to tree's age and condition? BSRD is only present in roots and lower bole. In the early stages of the disease only a few roots may be infected, and the stain will not be seen in the xylem above ground. Age and condition do not affect the susceptibility of a tree to black stain but may determine how long it takes to die. A large old tree may take a longer time to show symptoms and die than a smaller tree with a less extensive root system.

10. Will the present drought's end result in the disease gradually subsiding or will the delayed effects of this stress become evident in several years? There is no clear relationship between drought stress and severity of BSRD, except that the fungus may grow better in moist soil; thus there may be increased losses to the disease when precipitation increases.

11. Are there other P. monophylla woodlands with such a severe infestation or is this "the worst"? Yes, there are other areas with similarly severe pinyon BSRD. For example, at Baldwin Lake, San Bernardino National Forest, California, BSRD was first noted as a widespread problem in 1941 (Wagener and Mielke 1961). At present (50 years later) there are high levels of mortality on the site; there are also green trees, and the stand continues to be overstocked. One visible difference between pinyon stands on the San Bernardino National Forest and those at Chimney Peak is that the former have more juniper and mountain mahogany interspersed with the pinyons.

The disease also infects Pinus edulis, the Colorado pinyon. In 1945, plots were established in Mesa Verde National Park to study the disease. When FPM personnel revisited one area in 1989, the disease had disappeared and healthy young pinyons occupied the site (E.M. Sharon pers. comm.)

12. What monitoring techniques have been used in other, similar pinyon situations and can monitoring in Chimney Peak be coordinated with and complement these projects? Refer to Wagener and Mielke (1961), Landis and Helburg (1976), and Sharon and Johnson (1987) for the types of studies that have been done. The disease in other host trees has been reviewed in Harrington and Cobb (1988). Contact Laura Merrill (Forest Pest Management, San Bernardino National Forest, 714-383-5588) for information on current research.

The following questions concerning black stain in pinyon are unanswered and are of interest in managing the disease:

1. How fast do disease centers expand?
2. Do all centers expand? Do some die out?
3. How common is it for new centers to form -- is most new mortality in expanding, established centers or in new centers?
4. Is there any evidence of long term survival of natural regeneration in older centers?
5. Is there any evidence that past control activities or other human interventions have caused new mortality?